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Resource management and charging in ATM networks

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Abstract

This paper investigates the relationship between resource management and charging in ATM networks and discusses their parameters. Resource management schemes suitable for usage-sensitive and time-sensitive charging are proposed.

Keywords: ATM networks; Charging; Resource management; Connection admission control

1. Introduction

Among the various requirements for ATM networks is the implementation of appropriate tariff structures (types of charging). There is a close relationship between charging and resource management in ATM networks. On the one hand, charging affects subscriber behavior and, as a result, traffic characteristics. On the other hand, parameters related to resource management can be used as parameters for charging.

Examples of parameters related to resource management for ATM bearer services are shown in Fig. 1. Among these parameters, those which are intrinsic to a call can be used for charging purposes. These parameters are marked by large open and closed circles in Fig. 1. The parameters cell delay variation (CDV) and subscriber line class are somewhat controversial. These parameters can be used as parameters for subscriber line charging but they are not intrinsic call parameters. For example, the charge for a call from a subscriber connected at an S_B reference point on a customer premises network (CPN) depends on CDV within the CPN (Fig. 2). Therefore, if the CPN changes, the charge may vary for the same call. Even when the CPN accommodating the destination subscriber changes, the charge paid by the originating subscriber can change. However, if there is no shaping at the network ingress, CDV directly affects the amount of resources needed for each connection.

2. Usage-sensitive charging and time-sensitive charging

Charging principles can be classified into two categories: usage-sensitive charging and time-sensitive charging. In existing packet switched networks, usage-sensitive charging is used in many countries. That is, a user pays according to the number of packets he sends. Even in ATM networks, a data communication user is likely to prefer usage-sensitive charging. On the other hand, the telephone network uses time-sensitive charging. That is, a user pays according to the length of time the call connection is held open, regardless of the actual time spent talking. Time-sensitive charging is simple because it does not require usage monitoring.

If an ATM network is to offer usage-sensitive charging, its resource management must be designed ac-

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○ Origination/destination (or distance between O and D)
○ Holding time
○ Value of a source traffic descriptor
? Cell delay variation (CDV) in a CPN and in a network
● Statistics of an actually offered (or carried) cell stream
? Subscriber line class
○ QoS class
○ Call attempt (access charge)
○ Number of connections and points
● Number of bursts (in FRP)
· Traffic characteristics of other subscribers
· Network configuration
· Bandwidth of VPs in a network
○ Service class
○ Date/time

○,● Parameters available for charging
● Parameters limited to usage-sensitive charging
? Controversial parameters

Fig. 1. Examples of parameters related to resource management for ATM bearer services.

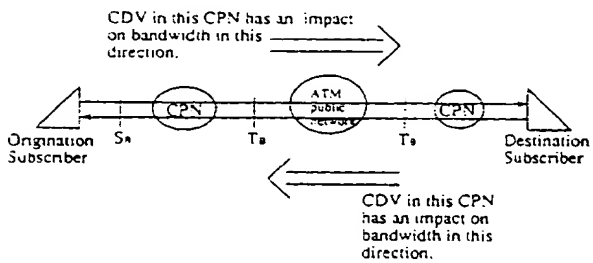

Fig. 2. Network configuration and impact of CDV.

cordingly. In other words, the resource management must measure the actual usage of resources assigned to each connection. For example, resource management must use the statistics of actually offered or carried cells or bursts (see closed circles in Fig. 1). This is because the ITU-T standard and the ATM Forum UNI specification for the source traffic descriptor only specify the upper bounds on cell rate statistics and cannot specify the actual number of cells.

The amount of resources assigned to each connection is determined by the connection admission control (CAC) based on a source traffic descriptor. If this amount is fixed during the whole duration of a call irrespective of the number of generated cells, we should use time-sensitive charging instead of usage-sensitive charging.

3. Dynamic CAC for usage-sensitive charging

To perform resource management for services requiring usage-sensitive charging, we propose the use of traffic measurement based CAC. This is a dynamic CAC [1,5]. It plays an important role in high-speed data communication networks implemented using ATM together with a congestion control that regulates traffic according to congestion notification [2]. The dynamic CAC is based on an upper bound for the cell loss ratio (CLR) derived from the stationary distribution of the number of cells arriving at each VP during a period of fixed duration. Let r be the number of cells which can be served in the considered period and let $(p(0), p(1), \ldots)$ be the distribution of the number of cells arriving. We have

$$\mathrm{CLR} \le \sum_{k=0}^{\infty} [k-r]^{+} p(k) / \sum_{k=0}^{\infty} k p(k) \qquad (1)$$

The network measures the number of cells arriving at each VP in successive r-cell periods and estimates $(p(0), p(1), \ldots)$. Let this estimate be $(\hat{p}(0), \hat{p}(1), \ldots)$.

When a connection with a peak cell rate of $1/T$ requests admission, the network can estimate the new distribution of the number of cells arriving during an r-cell period if the connection were admitted to be

$$(0_R, \hat{p}(0), \hat{p}(1), \ldots), \qquad (2)$$

where 0_R denotes an R-tuple of zeros and $R = r/T$. This is because the maximum number of cells arriving during r is R and $p(k)$ becomes the probability that $k+R$ cells will arrive if the number of cells arriving from the connection is always R. (When there is non-negligible CDV, the conversion formula shown in [5] should be used.)

Using (1) and (2), the dynamic CAC decides whether to admit the connection as follows (Fig. 3): the connection is admitted if and only if the following quantity is less than the target value of CLR:

$$\sum_{k=R}^{\infty} [k-r]^{+} \hat{p}(k-R) / \sum_{k=R}^{\infty} k p(k-R). \qquad (3)$$

The dynamic CAC cannot assure the CLR objective but it sets the target value.

The dynamic CAC can reflect the actual usage of each connection: if a connection does not emit cells, the tail of $\{\hat{p}(k)\}$ (the estimated distribution of the number of arriving cells) becomes small. As a result, more connections can be admitted as is appropriate for usage-sensitive charging.

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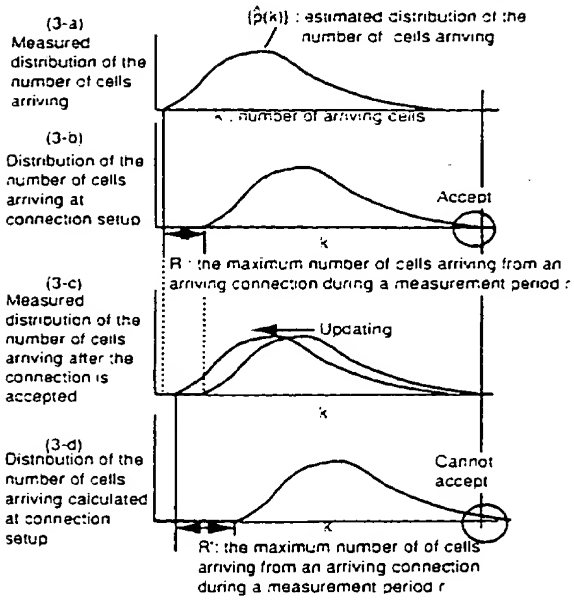

Fig. 3. Conceptual illustration of dynamic CAC.

4. CAC for time-sensitive charging

Resource management based only on a source traffic descriptor is suitable for time-sensitive charging. The proposed algorithm aims to provide enough bandwidth to convey any traffic stream that conforms to the negotiated source traffic descriptor values [4–6]. In other words, the following algorithm performs CAC assuming the worst cell arrival process compatible with the traffic descriptor.

Consider periods of length T. Here, T is the time for the VP to transmit K cells, where K is the buffer size. (If we cannot assume that the cell arrival process is ergodic, T must be set to the time to transmit $K/2$ cells by the VP.) Let the maximum number of cells arriving at the VP from the ith VC be R_i and let the average number be A_i. Then, if the cell arrival process is stationary (and ergodic), the cell loss ratio can be upper bounded as follows [5]:

$$\mathrm{CLR} \leq \frac{\sum_{k=0}^{\infty}[k-r]^{+}\theta_1 * \cdots * \theta_n(k)}{\sum_{k=0}^{\infty} k\theta_1 * \cdots * \theta_n(k)}. \tag{4}$$

Here,

$$r = \begin{cases} K, & \text{if the process is stationary and ergodic,} \\ K/2, & \text{if the process is stationary,} \end{cases}$$

$*$ denotes convolution, and

$$\theta_i(j) = \begin{cases} A_i/R_i, & j = R_i, \\ 1 - A_i/R_i, & j = 0, \\ 0, & \text{otherwise.} \end{cases} \tag{5}$$

If the 1st through $(n-1)$th VCs are established and the nth VC requests admission, the above expression is evaluated. If the evaluated upper bound of the cell loss ratio is below the objective, the nth VC is admitted. In practice, a Γ distribution approximation is useful for calculating this expression. The relationships between the source traffic parameters and R_i and A_i are as follows.

Let X_i be the peak cell rate of the ith VC, S_i the sustainable cell rate, and Y_i the burst tolerance. Then $R_i = \min(\lfloor 1 + (T + Y_i)A_i \rfloor, \lfloor 1 + X_i T \rfloor)$ and $A_i = S_i T$.

Modifications to the above relations are necessary when CDV is non-negligible, see [5].

5. Future directions

In a mature B-ISDN, usage-sensitive traffic will be able to share a VP with time-sensitive charging traffic [3,5]. In this case, the usage sensitive charging traffic can use the leftover bandwidth caused by CDV and by granularity as well as the unused bandwidth assigned to time-sensitive charging traffic. CLP can be used to assign usage-sensitve charging to part of a VC cell stream and time-sensitive charging to the other part. Users will be able to choose the ratio of usage-sensitve charging and time-sensitve charging.

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References

[1] Saito, H., and Shiomoto, K., Dynamic call admission control in ATM networks, *IEEE J. Select. Areas Comm.* 9 (7) (1991) 982–989.
[2] Chaki, S., Saito, H., Miyake, K., and Ohnishi, H., ATM network for high-speed data communication, *SICON 93*, 1993.
[3] Saito, H., Hybrid connection admission control in ATM networks, *ICC 92*, 1992.
[4] Saito, H., Call admission control in an ATM networks using upper bound of cell loss probability, *IEEE Trans. Comm.* 40 (9) (1992) 1512–1521.

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28(1996) March, No. 5, Amsterdam, NL

[5] Saito, H., *Teletraffic Technologies in ATM Networks*, Artech House, Boston (1994).

[6] Aida, M. and Saito, H., Traffic contract parameters and CAC guaranteeing cell loss ratio in ATM networks, *APSITT 93*, 1993.

Hiroshi Saito graduated from the University of Tokyo with a B.E. degree in Mathematical Engineering in 1981, an M.E. degree in Control Engineering in 1983 and received Dr.Eng. in Teletraffic Engineering in 1992. He joined NTT in 1983. He is currently responsible for teletraffic issues in ATM networks at the NTT Telecommunication Networks Laboratories as a Distinguished Technical Member. He contributes ITU-T and ATM Forum Traffic Management Subworking Group. He received the Young Engineer Award of the Institute of Electronics, Information and Communication Engineers (IEICE) in 1990 and the Telecommunication Advancement Institute Award in 1995. Dr. Saito is a senior member of IEEE, and a member of the IEICE, and the Operations Research Society of Japan. He is the author of the book, Teletraffic Technologies in ATM Networks (Artech House).